LABORATORIO ELETTRONICA L-A

2009-10

Seminario:

Strumentazione Avanzata per Misure a Basso Rumore

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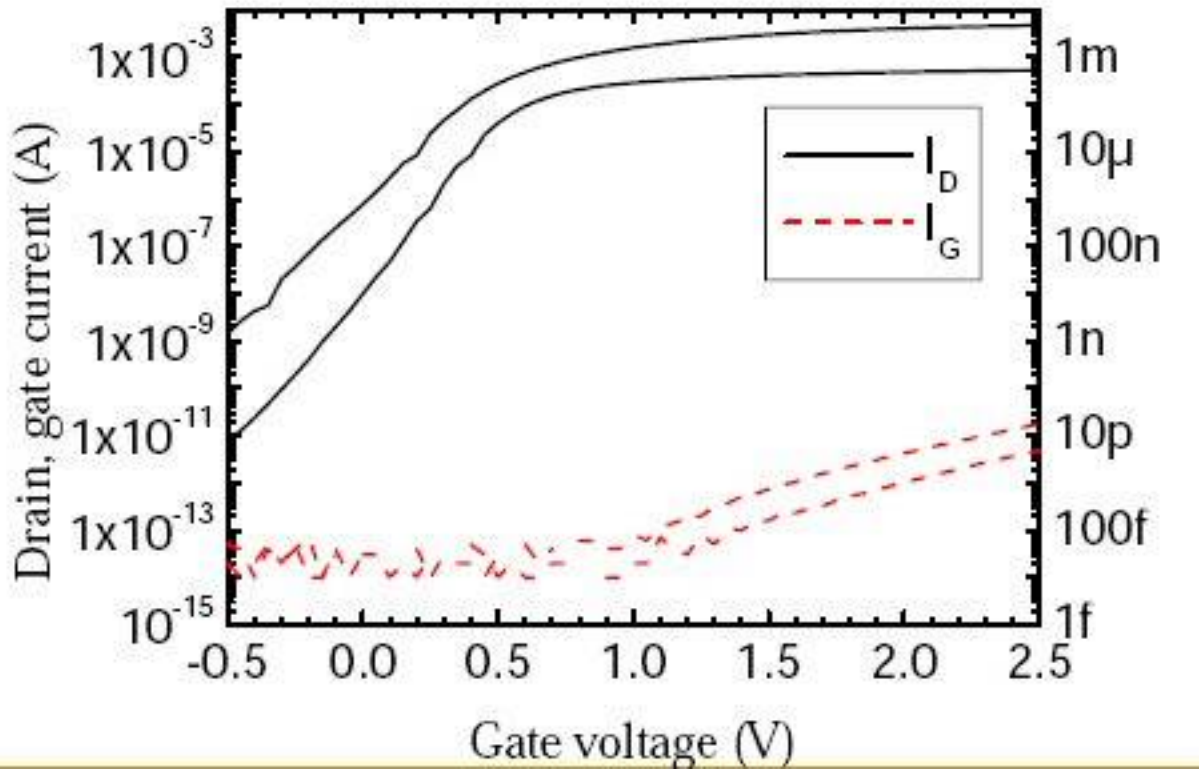
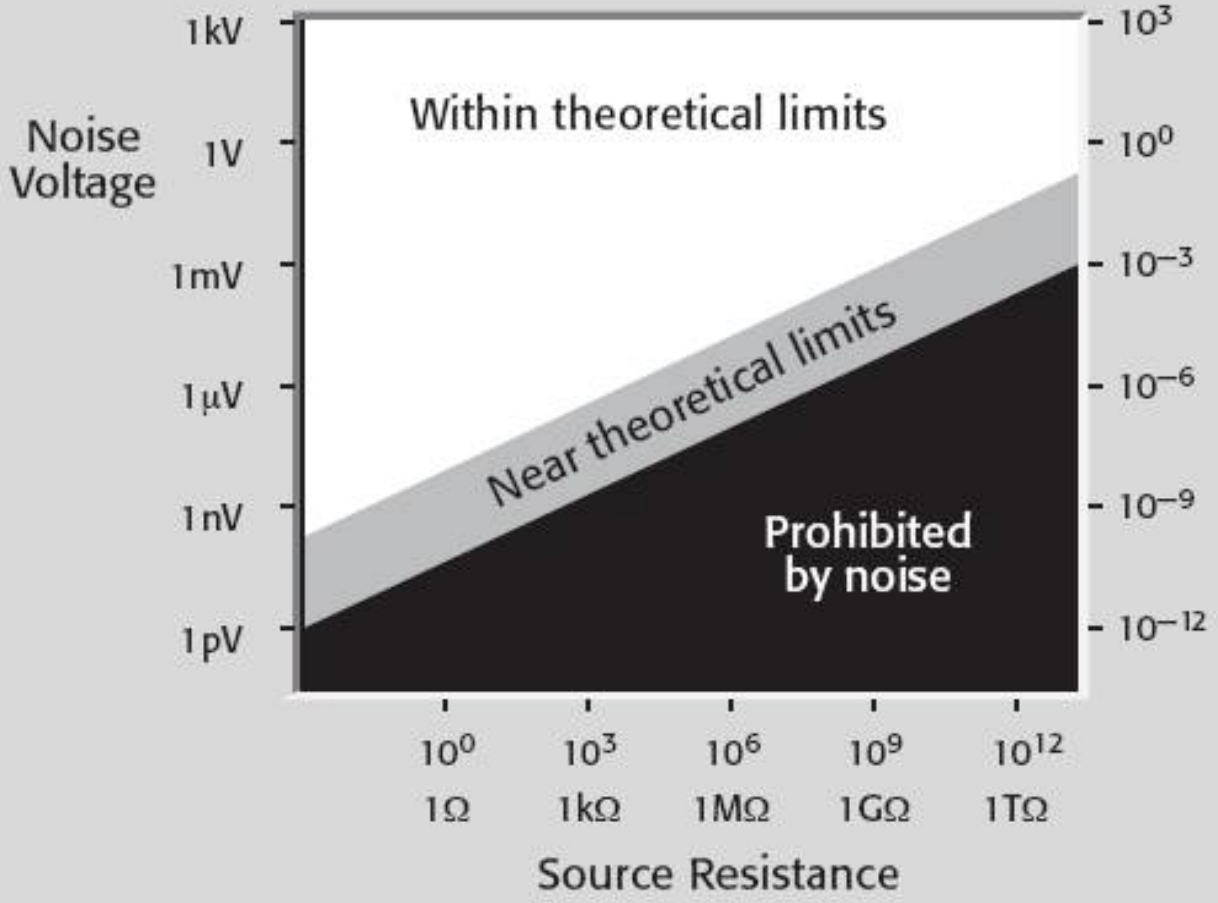
Cosa vogliamo misurare?

- **Performance dei transistori (I_{ON} , I_{OFF} , ecc…)**



THEORETICAL MEASUREMENT LIMITS



Instrument specification (1)

- **SENSITIVITY** - the smallest *change* in the signal that can be detected.
- **RESOLUTION** - the smallest *portion* of the signal that can be observed.
- **REPEATABILITY** - the closeness of agreement between *successive* measurements carried out under the same conditions.
- **REPRODUCIBILITY** - the closeness of agreement between measurements of the same quantity carried out with a stated *change in conditions*.
- **ABSOLUTE ACCURACY** - the closeness of agreement between the result of a measurement and its true value or accepted *standard value*. Accuracy is often separated into gain and offset terms.

Instrument specification (2)

- **RELATIVE ACCURACY** - the extent to which a measurement accurately reflects the *relationship* between an unknown and a *reference value*.
- **ERROR** - the *deviation* (difference or ratio) of a measurement *from its true value.* Note that true values are by their nature indeterminate.
- **RANDOM ERROR** - the *mean* of a large number of measurements influenced by random error *matches the true value*.
- **SYSTEMATIC ERROR** - the *mean* of a large number of measurements influenced by systematic error *deviates from the true value*.
- **UNCERTAINTY** - an estimate of the *possible* error in a measurement, i.e., the estimated possible deviation from its actual value. This is the opposite of accuracy.

ACCURACY

- **Instrument accuracy is usually specified as a percent of reading, plus a percentage of range (or a number of counts of the least significant digit).**
- **For example, a typical DMM accuracy specification may be stated as: ±(0.005% of reading + 0.002% of range).**
- **Accuracy may also be specified in ppm (parts per million). Typically, this accuracy specification is given as ±(ppm of reading + ppm of range).**

RESOLUTION

- **The resolution of a digital instrument is determined by the number of counts that can be displayed, which depends on the number of digits.**
- **A typical digital electrometer might have 5 1⁄2 digits, meaning five whole digits (each with possible values between 0 and 9) plus a leading half digit that can take on the values 0 or ±1.**

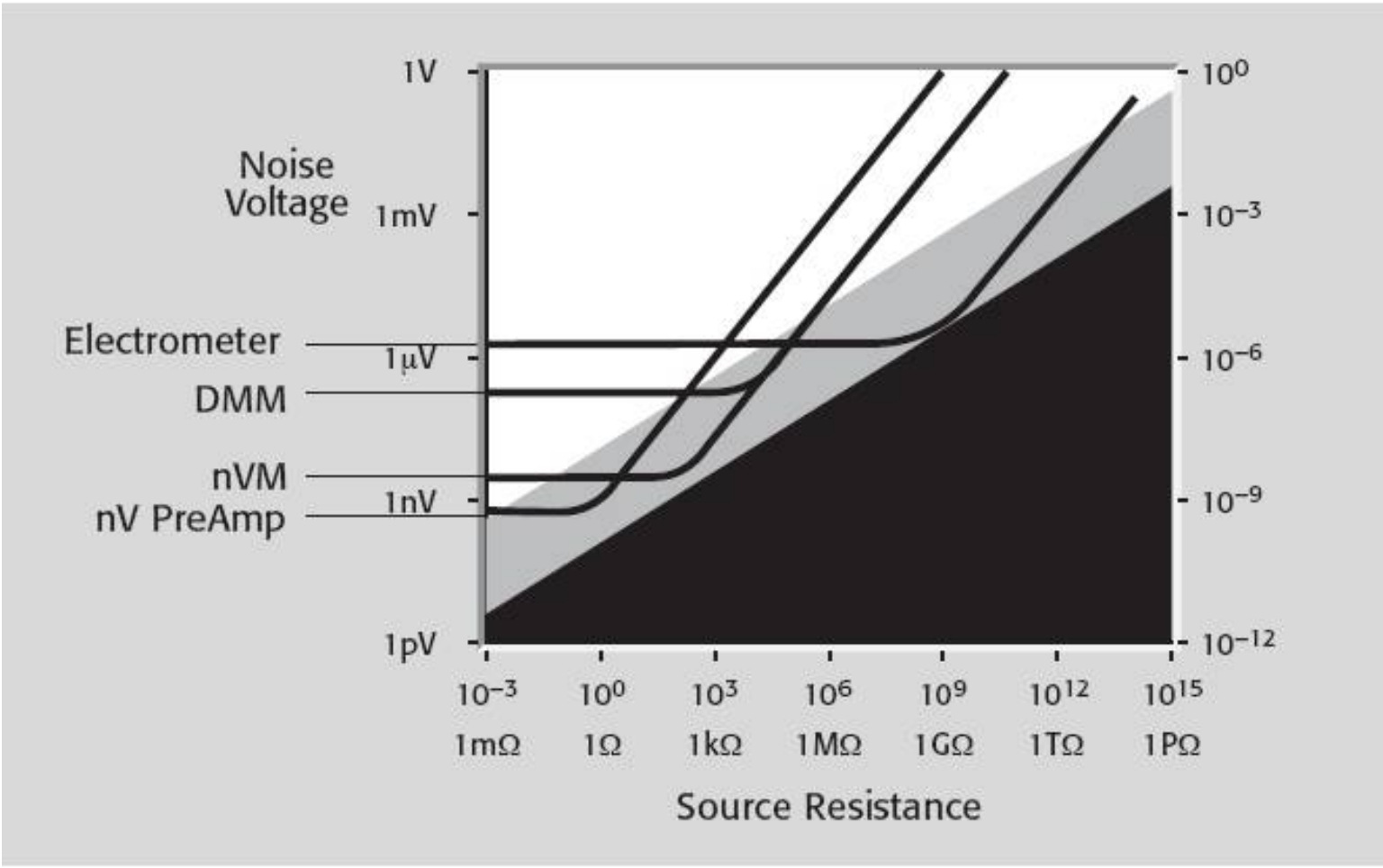
SENSITIVITY

- **The sensitivity of a measurement is the smallest change of the measured signal that can be detected.**
- **For example, voltage sensitivity may be 1μV, which simply means that any change in input signal less than 1μV won't show up in the reading.**
- **Similarly, a current sensitivity of 10fA implies that only changes in current greater than that value will be detected.**
- **The ultimate sensitivity of a measuring instrument depends on both its resolution and the lowest measurement range.**
- **For example, the sensitivity of a 5 1⁄2-digit DMM with a 200mV measurement range is 1μV.**

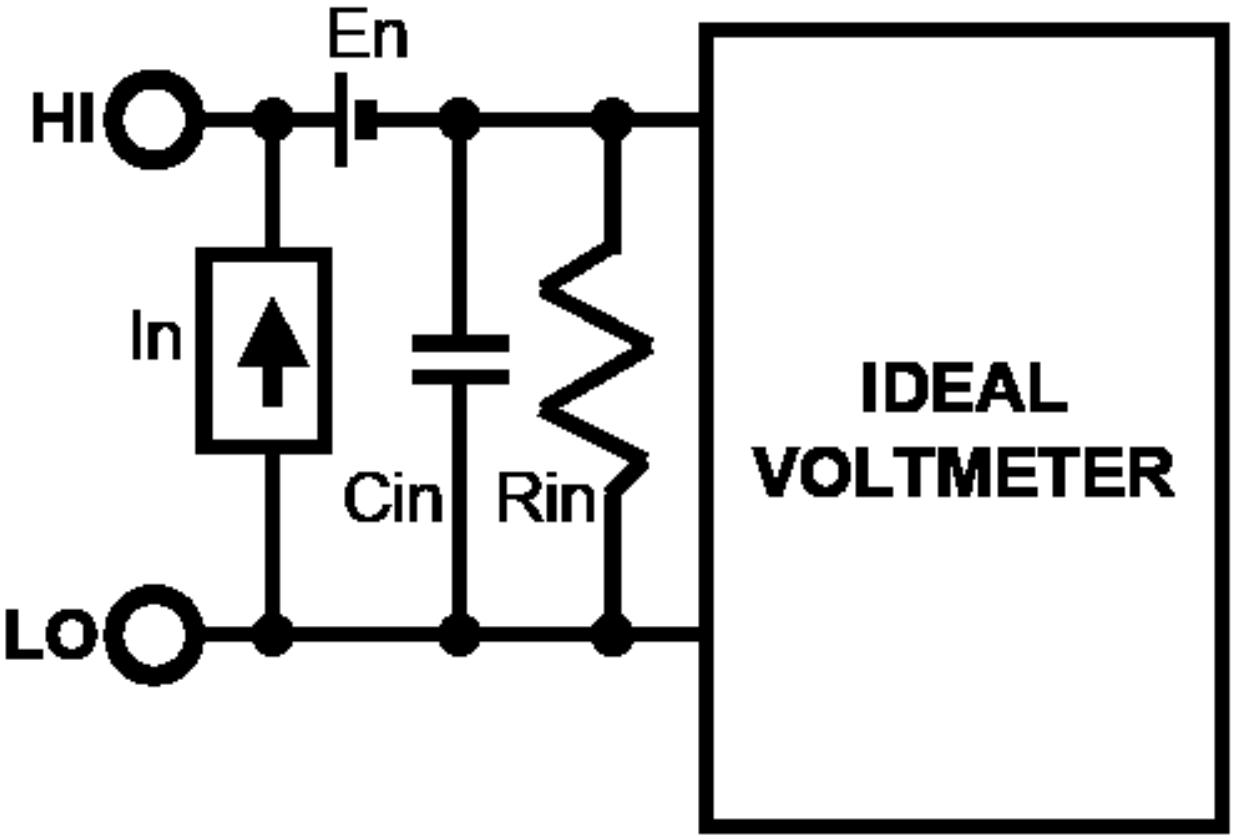
LOW LEVEL DC MEASURING INSTRUMENTS

- DMM (Digital Multimeters)
- Electrometers
- Picoammeters
- Nanovoltmeters

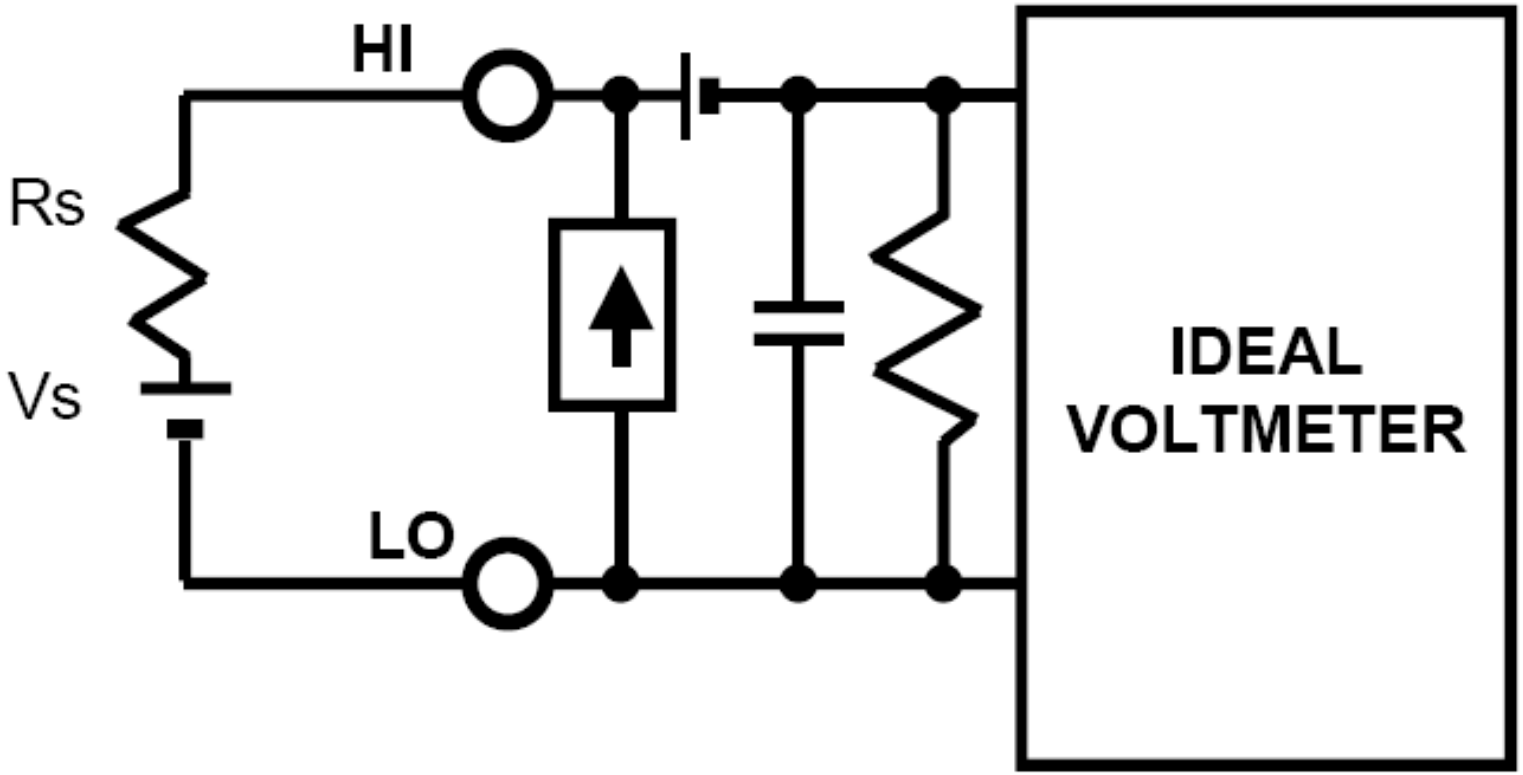
Electrometer, nVM, DMM limits



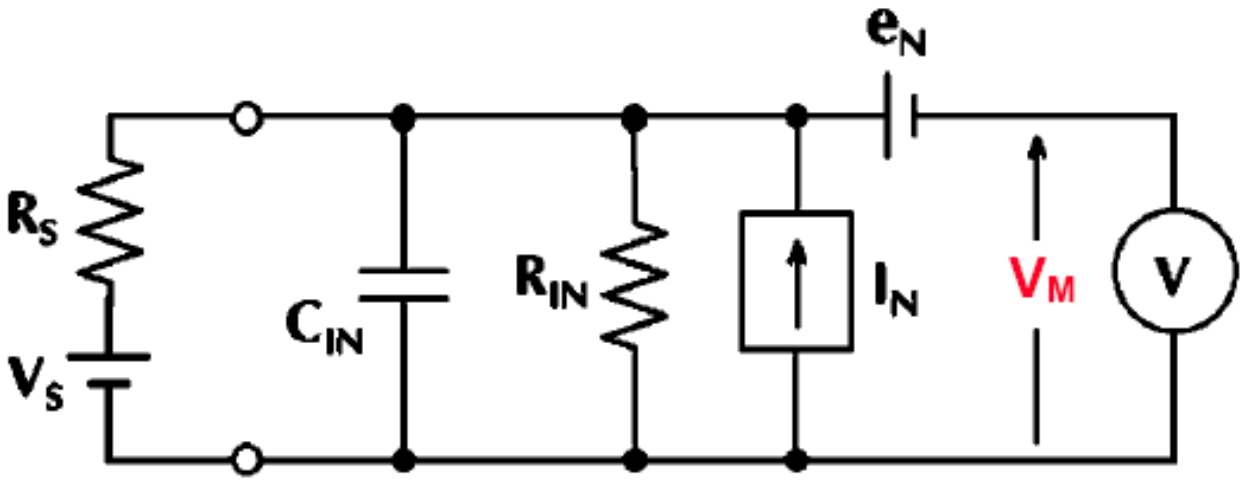
DMM/Voltmeter Input



DMM/Voltmeter source (1)

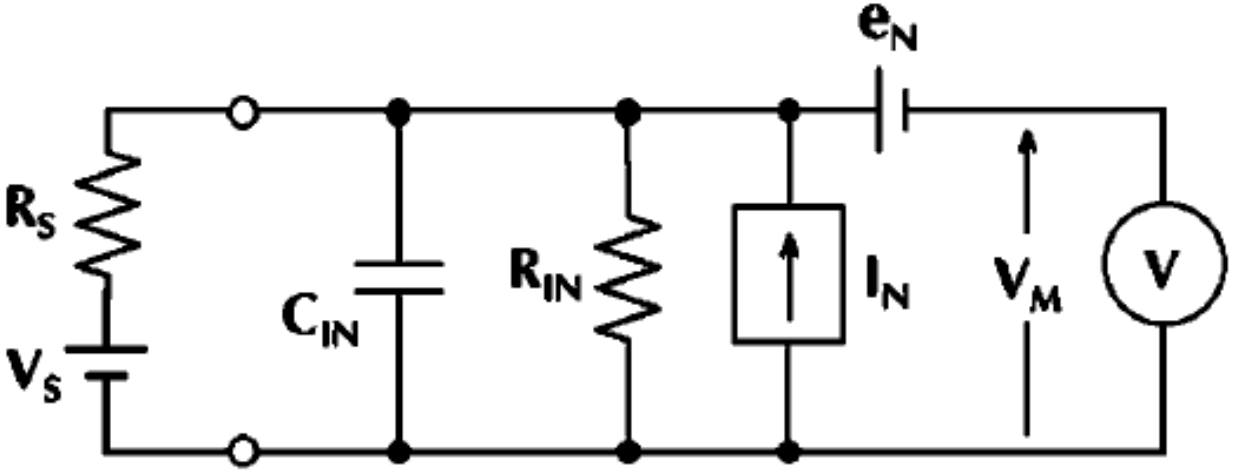


DMM/Voltmeter source (2)



$$V_M = V_S * \left[\frac{R_{IN}}{R_S + R_{IN}} \right] + e_N + I_N * \left[\frac{R_S R_{IN}}{R_S + R_{IN}} \right]$$

DMM/Voltmeter source (3)



$$V_M = V_S * \left[\frac{R_{IN}}{R_S + R_{IN}}\right] + e_N + I_N * \left[\frac{R_S\ R_{IN}}{R_S + R_{IN}}\right]$$

IF $R_{in} >> R_s$:
→ 1

IF $R_{in} >> R_s$:
→ R_s

IF $R_s \rightarrow 0$:
→ 0

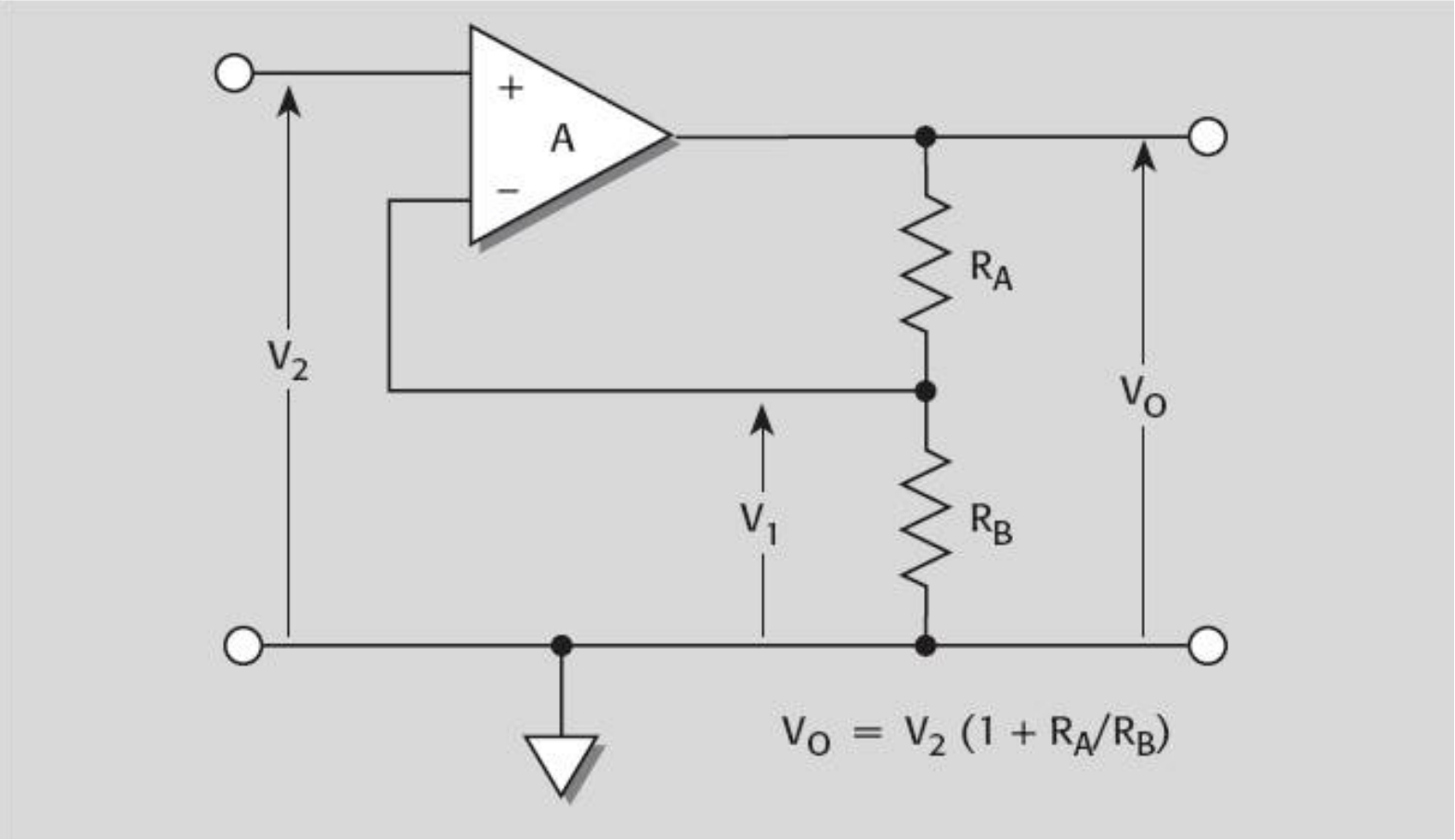
TYPICAL PARAMETERS (1)

Instr. Type	R_{IN}	e_N	I_N
DMM	1-10GΩ	0.5-5μV	10-100pA
nVmeter	1-10GΩ	1-10nV	5-50pA
Electrometer	10-200TΩ	2-20μV	1-10fA

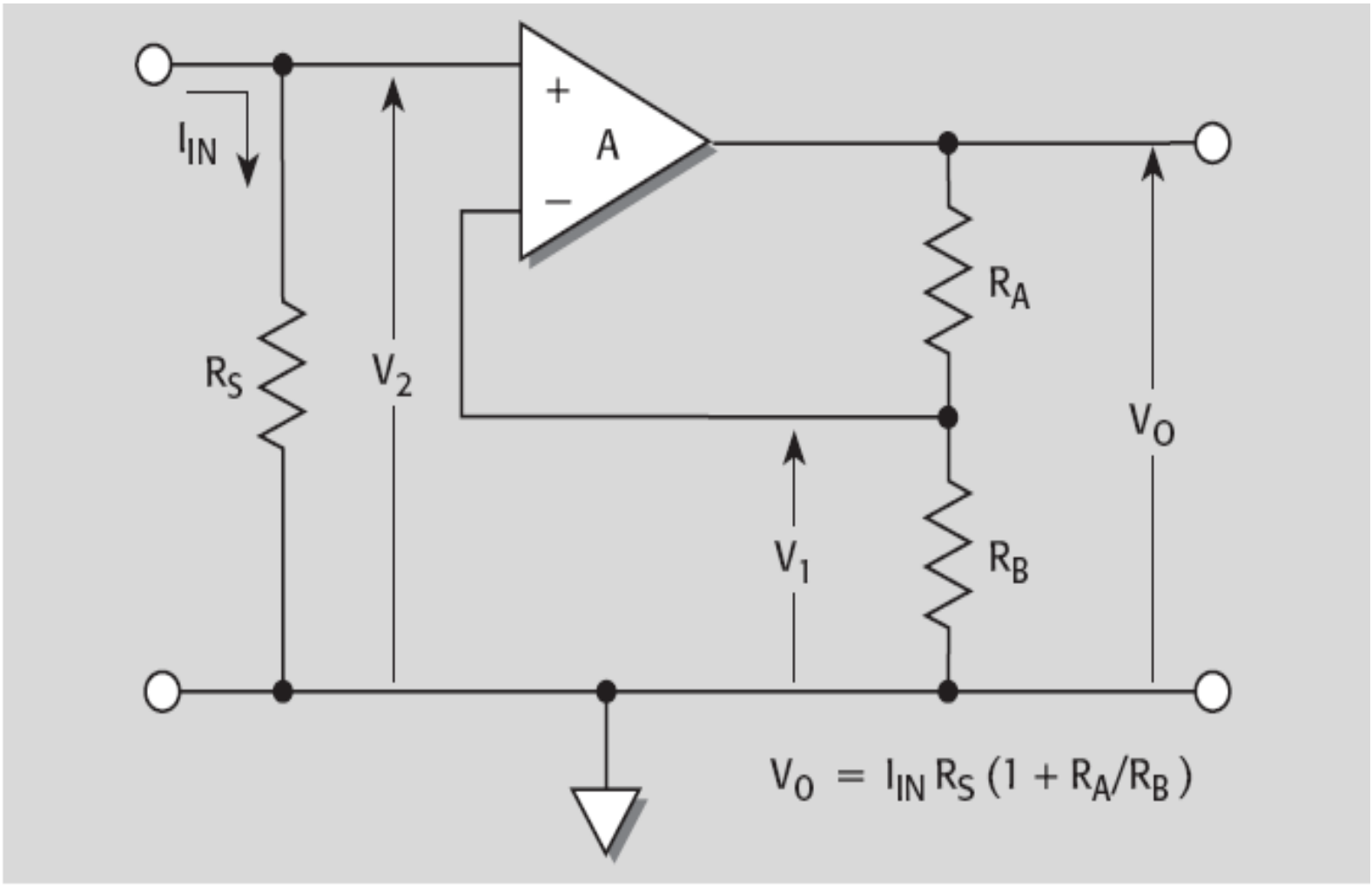
SPEED

- **Measurement speed is usually stated as a specific number of readings per second for given instrument operating conditions.**
- **Overall instrument measurement speed is affected by:**
  - **integration period**
  - **filtering**
- **However, changing these operating modes may also alter resolution and accuracy, so there is often a tradeoff between measurement speed and accuracy.**

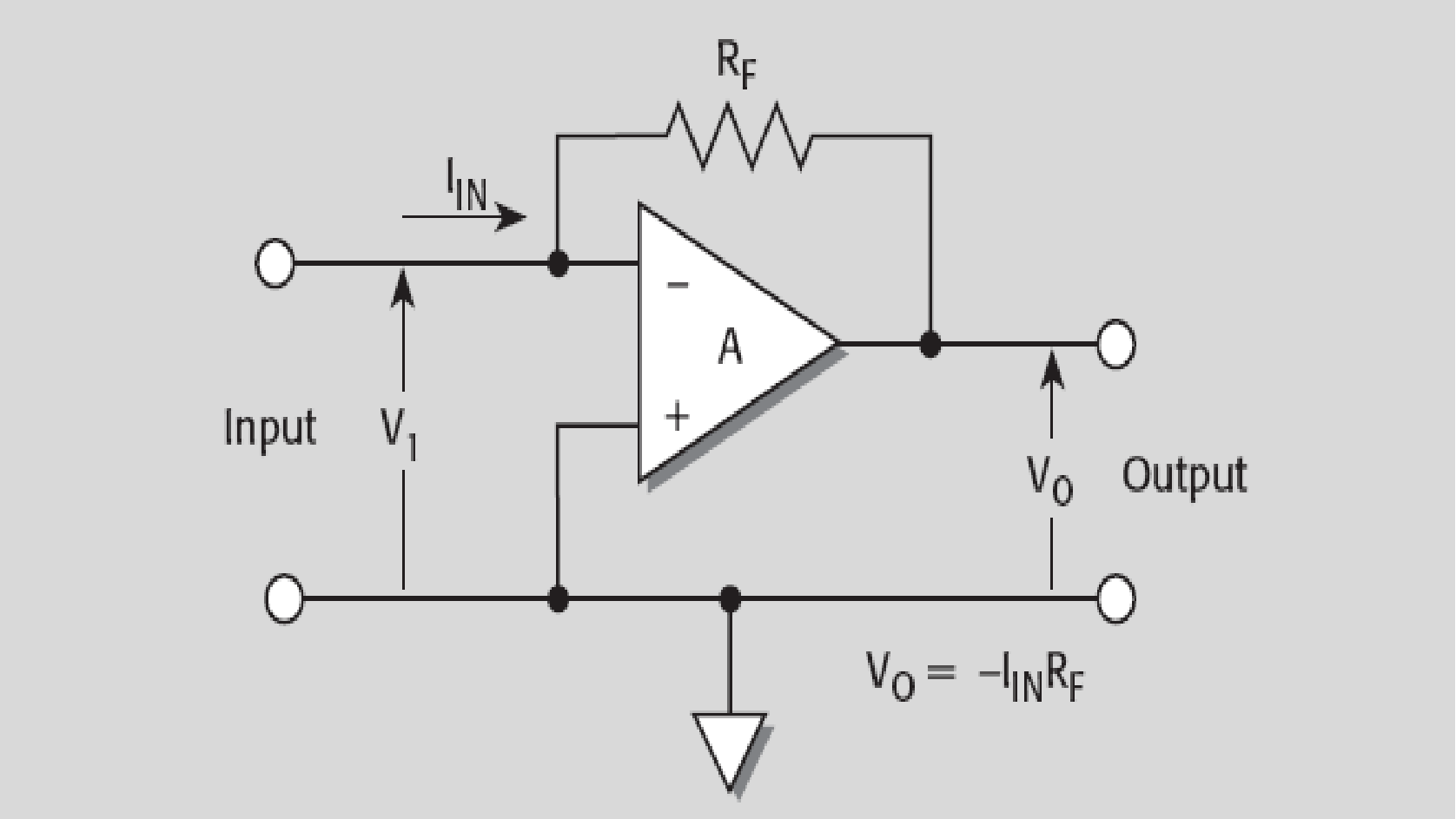
VOLTMETER CIRCUIT



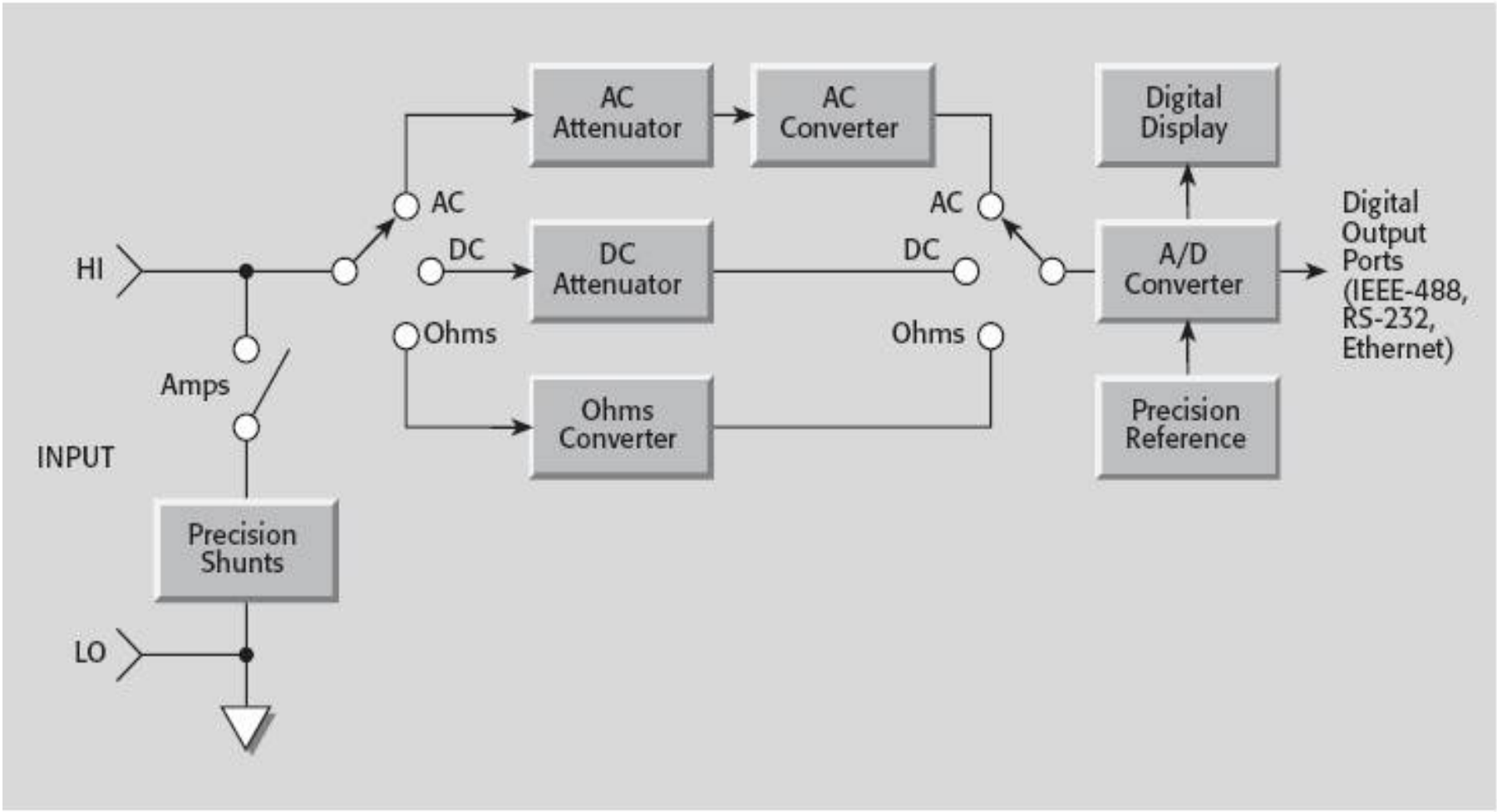
SHUNT AMMETER (1)



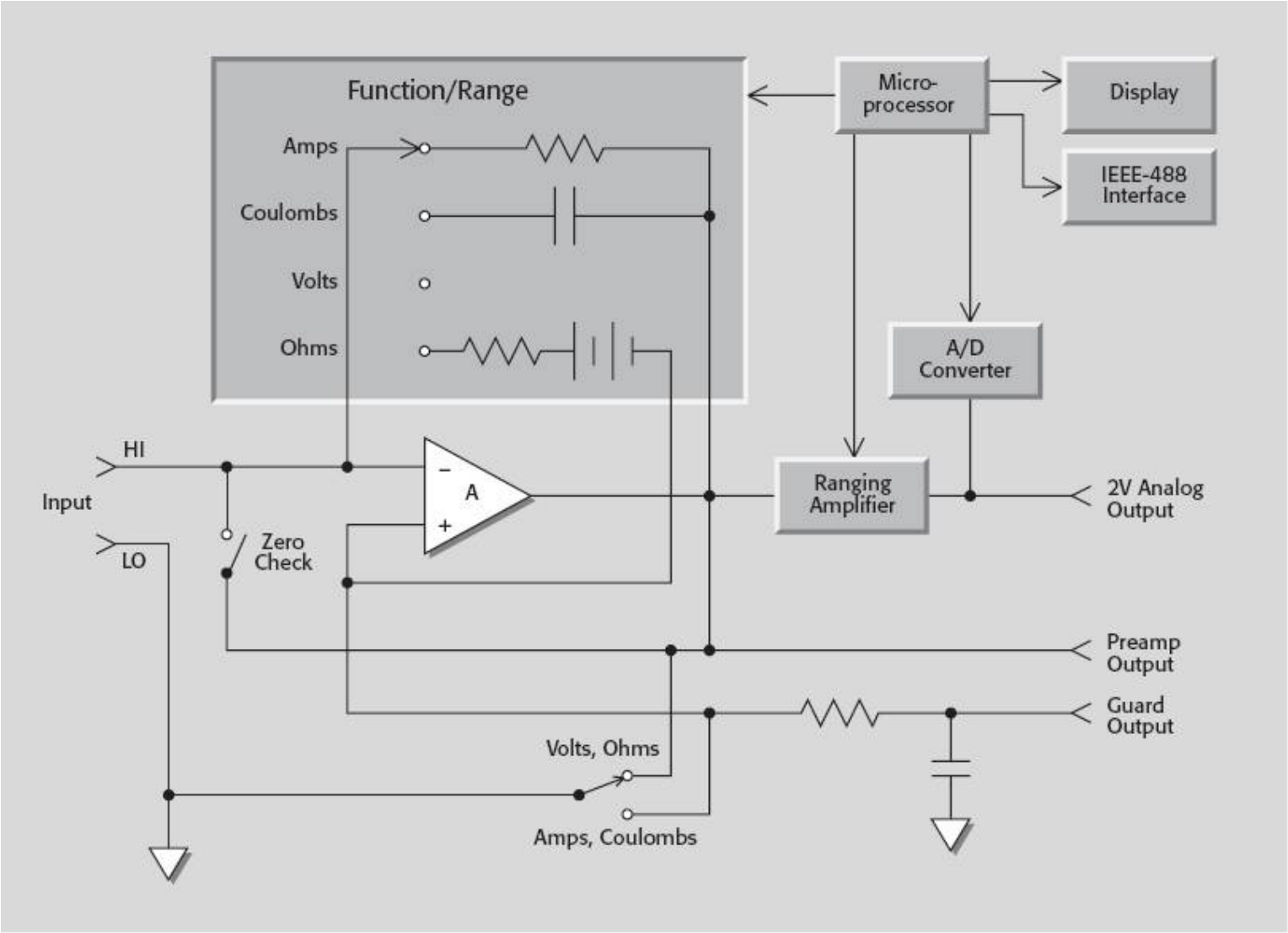
FEEDBACK AMMETER



DMM BLOCK DIAGRAM



DIGITAL ELECTROMETER

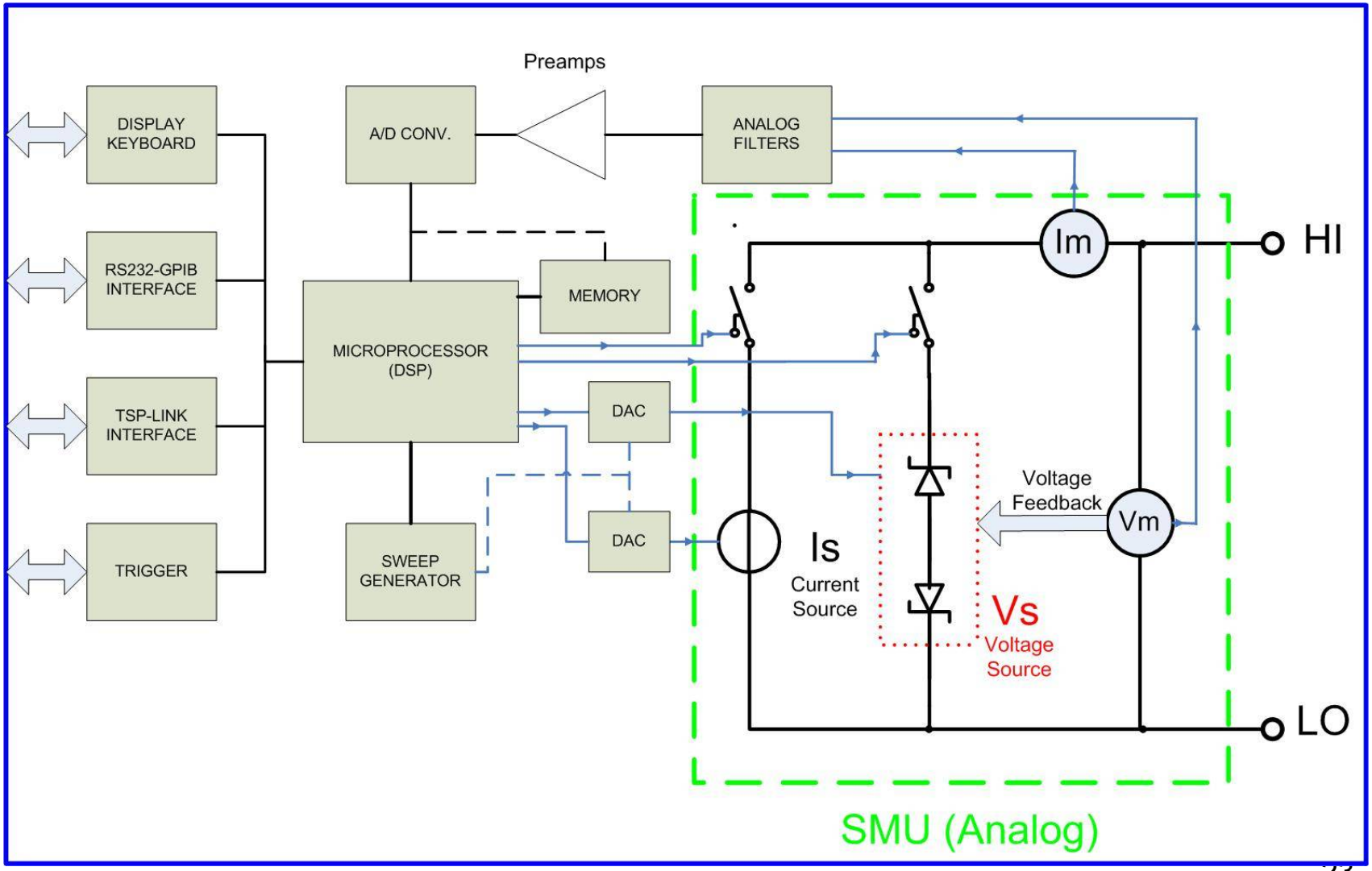


SMUs

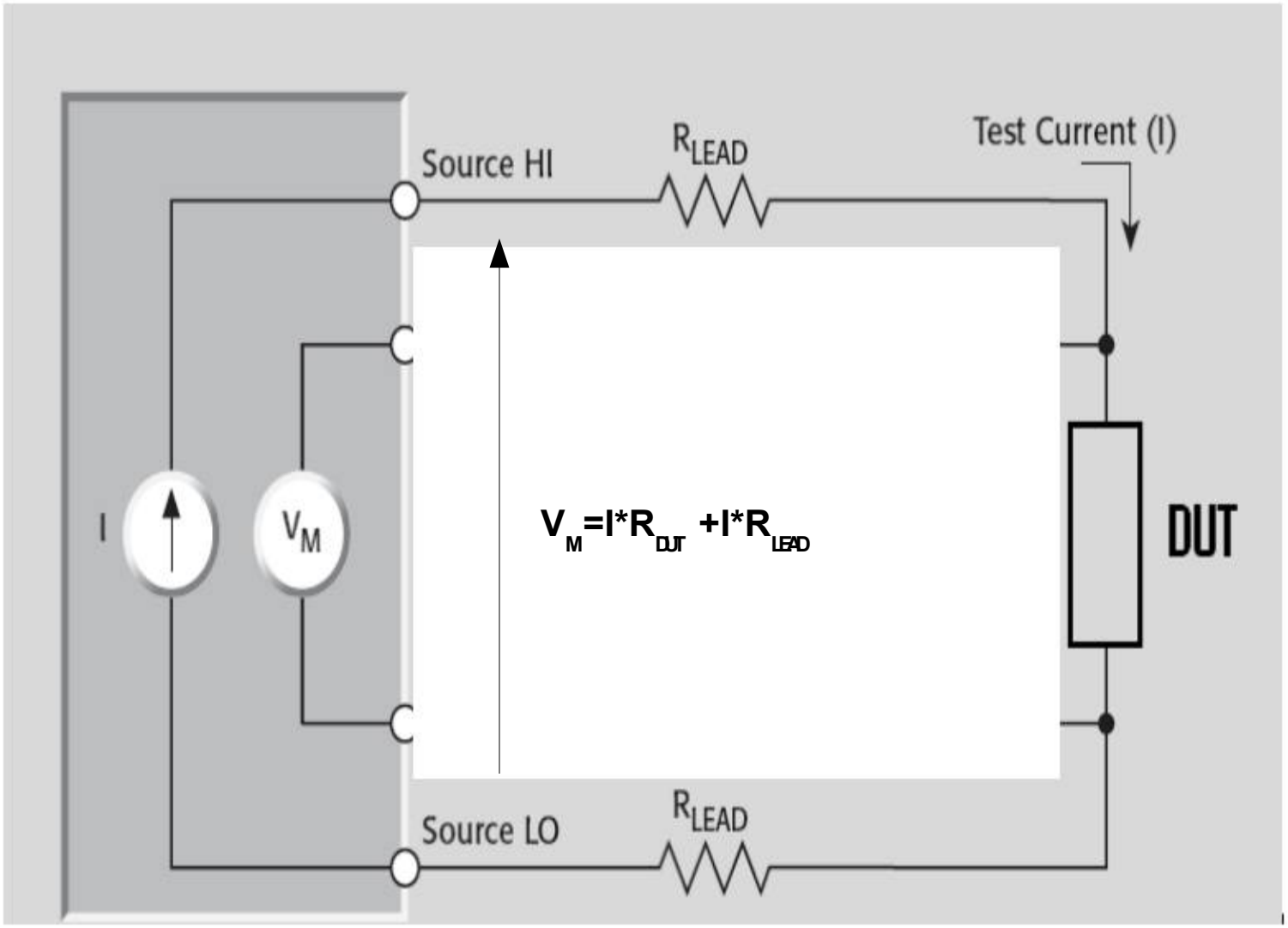
- **The SMU provides four functions in one instrument:**
  - **measure voltage,**
  - **measure current,**
  - **source voltage,**
  - **source current.**
- **Generally, such instruments can simultaneously source voltage and measure current or simultaneously source current and measure voltage.**

- **Voltage sense mode:**
  - **local sense: the voltage is measured at the output of the SMU (2-WIRE).**
  - **remote sense (4-WIRE): the voltage is measured at the device under test, eliminating any voltage drops due to lead resistance.**

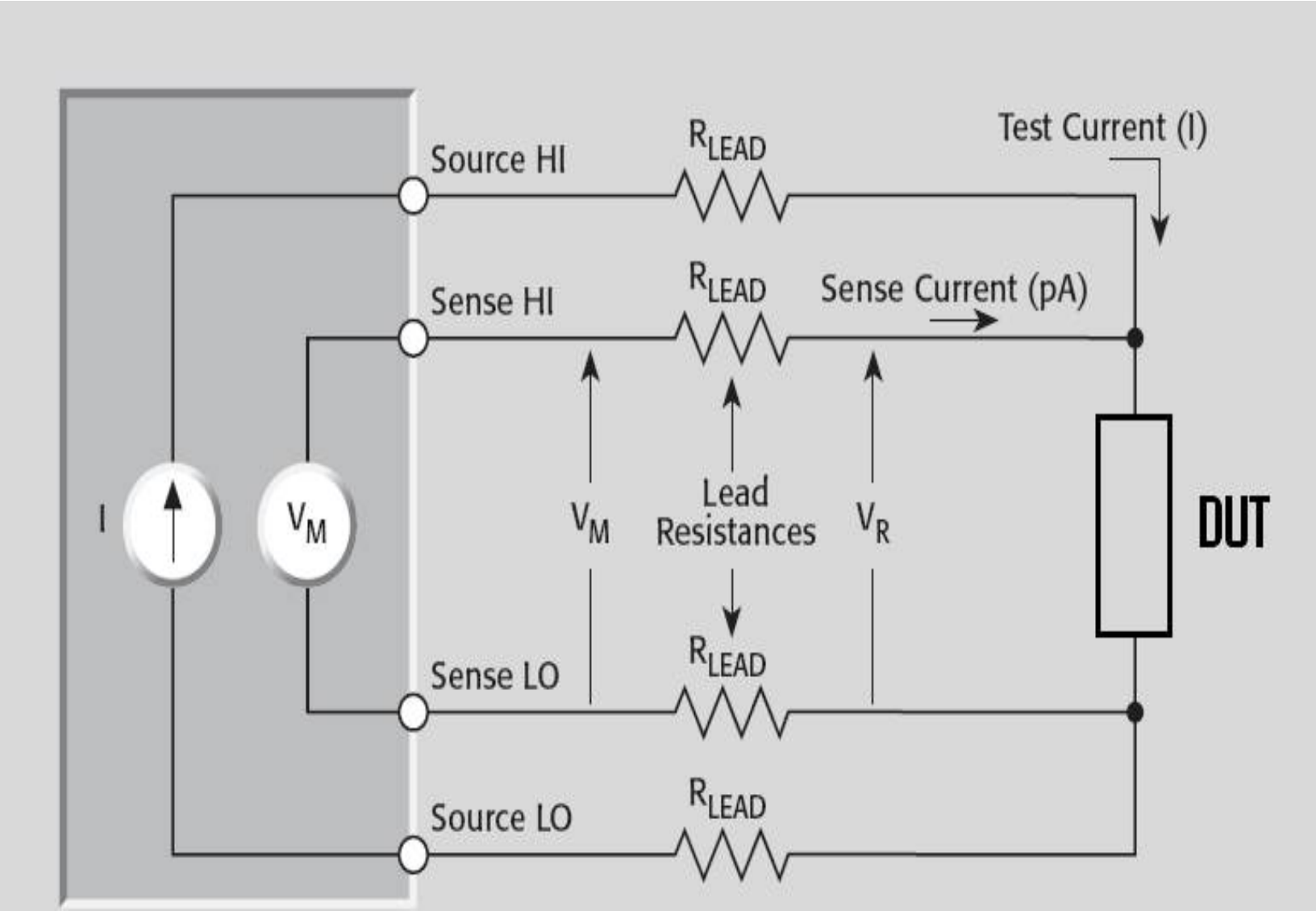
SMU BLOCK DIAGRAM



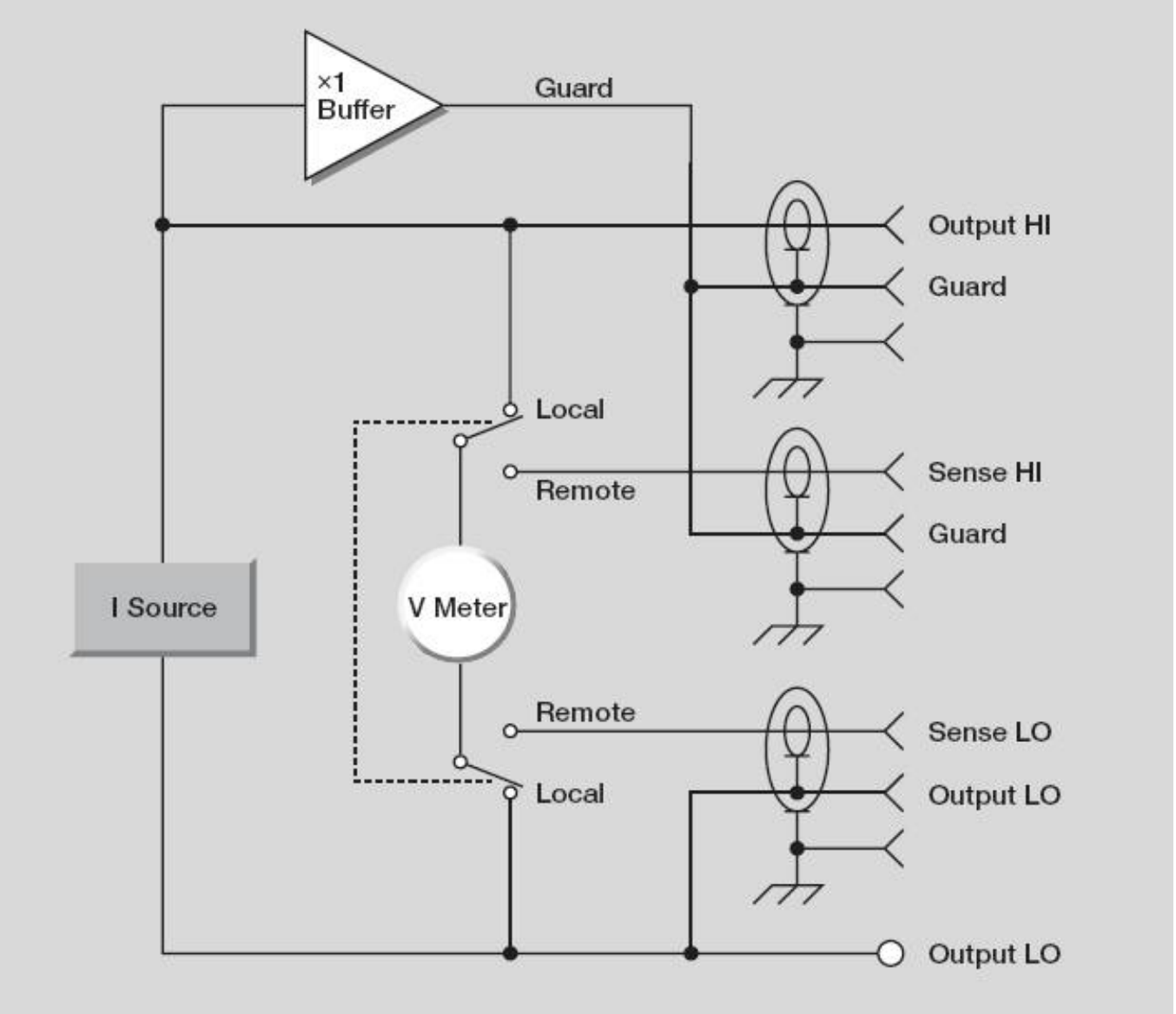
TWO-WIRES MEASUREMENT



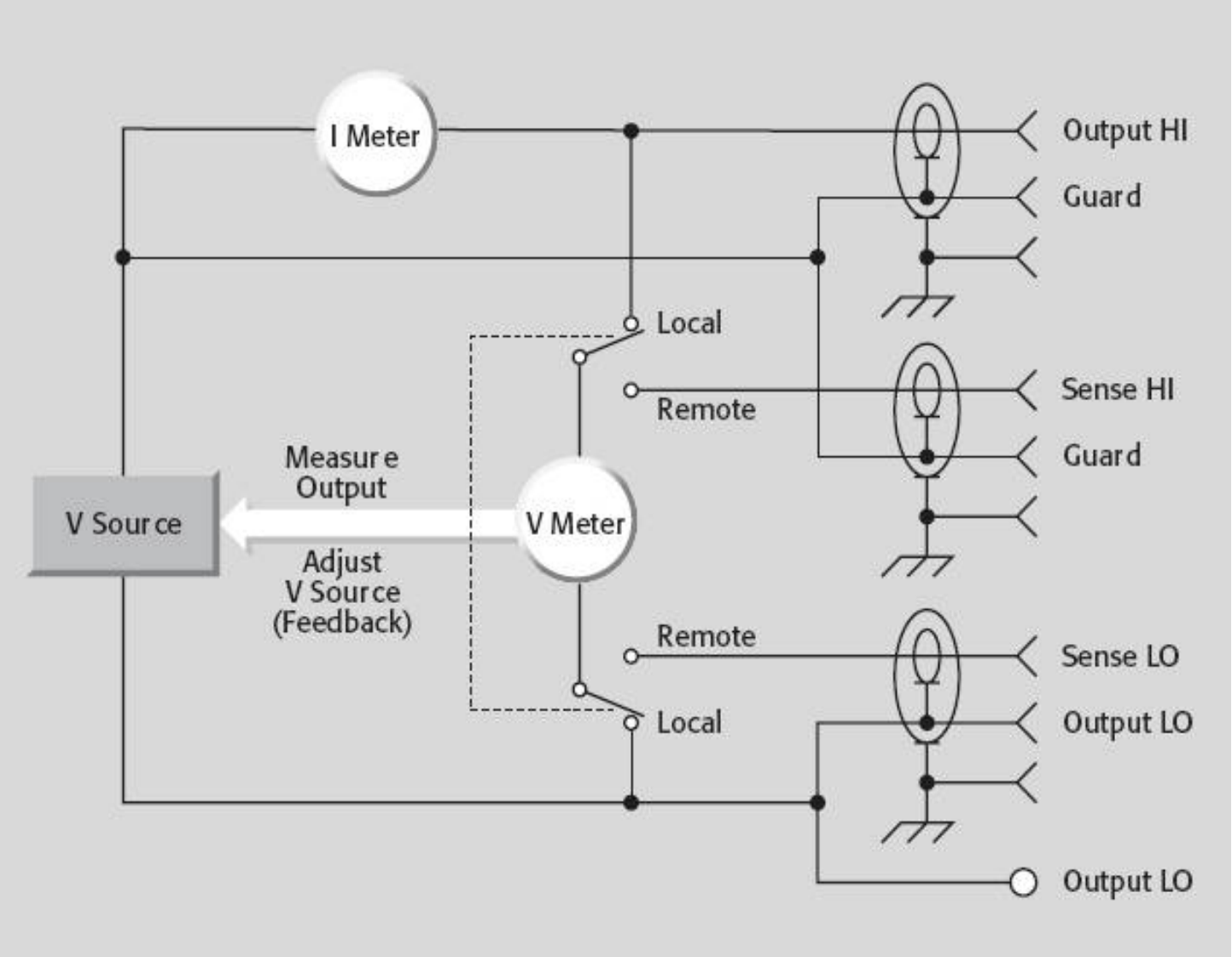
FOUR WIRE MEASUREMENT



SMU CURRENT SOURCE



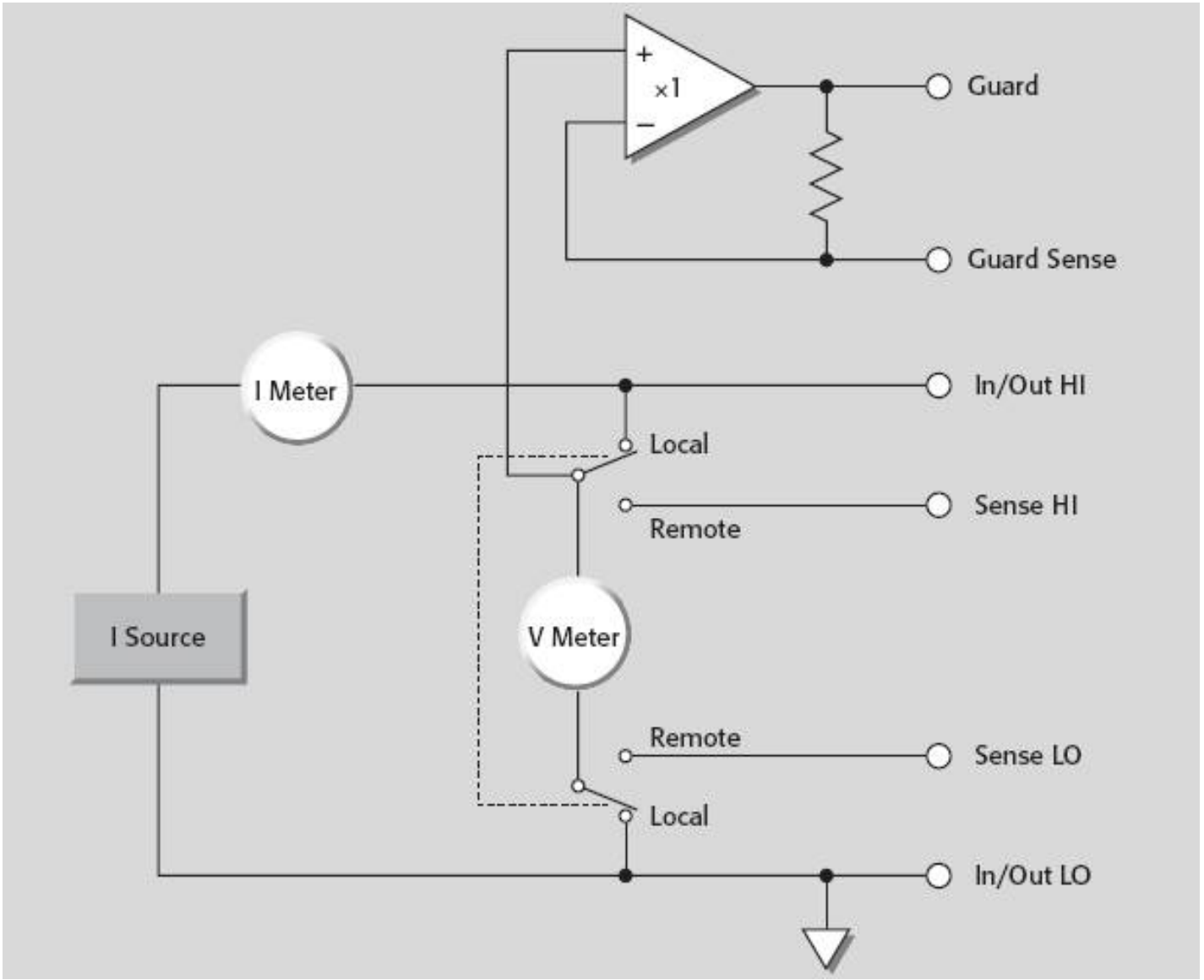
SMU VOLTAGE SOURCE



SOURCEMETERS

- **Like an SMU, a SourceMeter instrument can source current, source voltage, measure current and measure voltage.**
- **However, the SourceMeter instrument also has a sixth terminal, guard sense, which allows making more accurate measurements of networks.**

SOURCEMETER I SOURCE



SOURCEMETER V SOURCE